HEAT EXCHANGER CALCULATIONS EXAMPLE

The main condenser of a steam plant is at a pressure of 5 psia. Steam exits the turbine with a steam quality of 90%. The steam mass flow rate is 12,000 lb_m/hr. It exits the condenser as a saturated liquid. The condenser is cooled by seawater. The seawater injection temperature is 60°F. The seawater ~~mass~~ VOLUMETRIC flow rate is 800 gpm. The overall heat transfer coefficient for this heat exchanger is 125 $\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}$.

FIND: Required heat exchanger area [ft^2].

a) Is this a recuperative or mixed flow HX? RECUPERATIVE (INDIRECT CONTACT)

b) What type of flow pattern is there in this HX? CROSS FLOW (PHASE CHANGE)

c) What is the saturation temperature [°F] of the steam in the condenser? (You may round to the nearest whole integer – easier for enthalpy look up later in steam table 1.) T_{SAT} @ 5 PSIA = 162.24°F ≈ $\underline{\underline{162°F}}$

d) Calculate the heat transfer rate [Btu/hr] of the hot fluid (steam):

$$\dot{Q}_H = \underbrace{\dot{m}_H(c_p \Delta T)_H}_{\text{NOT USEFUL}} = \dot{m}_H (\Delta h)_H$$

$$\dot{Q}_H = \dot{m}_{STM}(h_{STM\,IN} - h_{STM\,OUT})$$

$$= 12{,}000 \frac{LBm}{HR}(1031.0 - 130.2)\frac{Btu}{LBm}$$

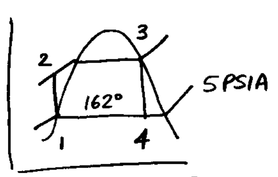
$$\boxed{\dot{Q}_H = 10.8096 \times 10^6 \frac{Btu}{HR}}$$

$$h_4 = h_f + x_4(h_{fg})$$

$$= 130.2 + (.9)(1000.9)$$

$$h_4 = \underline{\underline{1031.0}} \frac{Btu}{LBm}$$

$$h_1 = h_f = \underline{\underline{130.2}} \frac{Btu}{LBm}$$



$\Delta h = h_4 - h_1$

IN OUT

CONDENSER ④→①

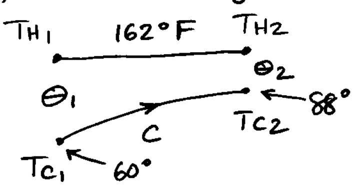
e) Calculate the exit temperature [°F] of the cold fluid (seawater):

$$\dot{Q}_H = \dot{Q}_C = \dot{m}_C(c_p \Delta T)_C = \dot{m}_{SW}(c_p(T_{SW\,OUT} - T_{SW\,IN})), \quad \dot{m} = \rho \dot{V}$$

$$10.8096 \times 10^6 \frac{Btu}{HR} = 64 \frac{LBm}{FT^3}\left(800 \frac{GAL}{MIN}\right)\left(\frac{1\ FT^3}{7.48\ GAL}\right)\left(\frac{60\ MIN}{HR}\right)\left(.94 \frac{Btu}{LBm\,{}^\circ R}\right)(T_{SW\,OUT} - 520^\circ R)$$

$$\boxed{T_{SW\,OUT} = 548^\circ R = 88^\circ F}$$

f) Calculate the Log Mean Temperature Difference [°F]:



$$\theta_1 = 162° - 60° = 102°F$$

$$\theta_2 = 162° - 88° = 74°F$$

$$\theta_m = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)} = \frac{(102 - 74)°F}{\ln\left(\frac{102}{74}\right)}$$

$$\boxed{\theta_m = 87.25°F}$$

g) Calculate the required HX area [ft^2]:

$$\dot{Q}_H = \dot{Q}_C = \dot{Q}(HX)$$

$$\dot{Q}(HX) = U A \theta_m$$

$$10.8096 \times 10^6 \frac{Btu}{HR} = 125 \frac{Btu}{HR\ FT^2\ {}^\circ F}(A)(87.25°F)$$

$$\boxed{A = 991.1\ FT^2}$$